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# NOCTURNAL DRAINAGE WIND CHARACTERISTICS IN TWO CONVERGING AIR SHEDS

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## 1. INTRODUCTION

The development of alternative energy sources and the expanded use of presently available resources inflict a heavy burden on the atmosphere. There is a growing concern regarding health and environmental effects of energy extraction operations. One such concern is public health in the vicinity of uranium mining and milling operations. Uranium mining and milling produce anomalously high local sources of $^{222}Rn$ due to the omnipresent high concentrations of $^{226}Ra$ (1600 year half-life parent of $^{222}Rn$) in the ores. The sources are in the form of open pit mines, vents from underground mines, ore piles, milling operations, mill tailings piles, and natural ore outcroppings. This variety of sources and the subsequent time and space variable meteorological transport field complicates environmental assessments. The assessments will proceed more efficiently and with higher confidence in the results if the important meteorology of these regions is understood and documented.

This paper presents the results of a summertime (Gedayloo, et al. 1979) and wintertime (Gedayloo, et al. 1980) study of the atmospheric transport characteristics under nocturnal flow conditions conducted in the Grants Basin of northwestern New Mexico. This area is composed of two major air sheds, one in the vicinity of Ambrosia Lake and the other near San Mateo. The Ambrosia Lake air shed is a shallow basin that drains from the Continental Divide toward the southeast and contains a majority of the Uranium mining and milling activity of the area. The San Mateo air shed runs east to west draining an area fed by Mount Taylor on the south and east and San Mateo Mesa to the north. The two air sheds converge to a narrow neck between Mesa Montanosa and La Jara. The terrain opens into the broader basin to the south.

As a first approach to the complicated meteorology of this area a rudimentary meteorological network was operated during two study periods. A summertime survey was conducted from May 18 to September 19, 1978 and a winter observation period ran from January [illegible] to April 4, 1979. The nocturnal drainage flow regime was emphasized in the analysis because of its potential for transporting effluents long distances with poor dilution due to lateral boundaries and shallow mixing depths. Four weather stations that record wind direction, wind speed, and temperature were placed in the locations shown in Fig. 2. It was assumed that these measurements could be interpreted to give the relative strength of the nocturnal drainage flow from each air shed and the total transport southward toward the Milan-Grants area.

The data from these monitoring stations were supplemented on a few occasions with vertical wind profile measurements.

## 2. EXPERIMENTAL ARRANGEMENT

Weather stations were installed approximately 1.5 m above ground in the Ambrosia Lake and San Mateo valleys at the following locations (see Fig. 2):

San Mateo Station was located near the San Mateo Creek close to the axis of this air shed and approximately 1.8 km east of the junction of Highways 53 and 509.

Ambrosia Lake Station was installed close to the axis of the Ambrosia Lake air shed. This location was 1.[illegible] km west of the junction of Highways 53 and 509.

Channel Station was placed close to the center of the confluence point of the valleys described above, approximately 2.1 km southwest from the junction of Highways 53 and 509.

Flats Station was installed approximately 6.5 km south southwest of the Channel Station. This station was added during the wintertime study in order to determine the characteristics of the drainage flow beyond the Channel region.

## 3. EXPERIMENTAL RESULTS AND ANALYSIS

The topography of the Grants Basin suggests the development of local upslope and downslope flow regimes due to a large diurnal surface temperature change and subsequent vertical temperature profiles on sloping surfaces. The results of the present experiment shows a distinctive diurnal wind pattern. Shortly after the surface air temperature begins to rise in the morning the wind direction shifts from its nocturnal value to a predominant daytime direction and the wind speed begins to gradually increase. Similarly, at the start of the temperature drop in the evening the wind direction changes and the speed begins to decrease.

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A highly repetitive nocturnal wind vector parallel to the local axis of each basin is established within a few hours after sunset and appears to be relatively insensitive to the large-scale pressure gradient. There are good indications that this is a local gravity driven drainage wind, which occurs in a shallow layer of very stable air and is decoupled by its stability from the general large-scale wind field above. Because of its boundary by San Mateo Mesa and Mesa Montanosa (Fig. 1), the drainage flow in the Ambrosia Lake air shed flows from the northwest. The drainage flow in the San Mateo air shed on the other hand, originating from the downslope flows from the San Mateo mountains, Mount Taylor, and San Mateo Mesa (Fig. 1), should have a northeasterly direction. Convergence of these two air flows through the channel between La Jara Mesa and Mesa Montanosa (Fig. 1) accounts for local acceleration as the air continues southward.

### 3.1 Surface Winds During Drainage Flow

The data collected during the experimental period were reduced to hourly averages of wind speed, direction direction range, and temperature and were analyzed for possible patterns in the local flow regimes. This analysis showed that over 60% of the nights during summer and approximately 65% of the nights during winter experienced a drainage flow. The remaining time this regime is influenced by local or large scale disturbances due to thunderstorm activities or strong gradient winds. It appears that the daily average reduction in temperature of approximately 25°C during summertime and less than 20°C during winter is one of the driving forces for the establishment of a local drainage flow in the Grants Basin. The data set, when examined for drainage flow characteristics in each air shed, reveals the following results.

1. The summertime onset and end times of the drainage flow vary slightly between the recording stations. These times are approximately 2200 MST and 0600 MST respectively. The duration time varies from 4 to 10 hours with a mean value of 8 hours. Wintertime onset and end times are 2030 MST and 0745 MST respectively with a mean duration of 11.6 hours. Summaries of these analyses are given in Tables 1 and 2.

2. The speed of the drainage flow varies from one recording station to the other because of the topographic variations. In San Mateo and Ambrosia Lake air sheds the average speed of the drainage flow is approximately 1.8 m/s and 1.5 m/s respectively during summer and 1.6 m/s and 1.5 m/s for the wintertime. The mean wind speed increases to approximately 2.5 $m\ s^{-1}$ in the channel area. It reduces slightly to about 2.2 $m\ s^{-1}$ south of the channel region, where the valley broadens, see Tables 1 and 2.

3. In order to determine the direction of drainage flow, wind roses were constructed from the data for the cases clearly indicating the presence of drainage flow. The results are shown in Figs. 3 and 4 for the summertime and the wintertime experiments respectively. As indicated by these wind roses, the main direction of nocturnal drainage flow is from east northeast in the San Mateo air shed and from north northwest in the Ambrosia Lake air shed. The wind roses for these two stations for the summertime experiment show other components of less frequent occurrence. The drainage flow direction at Channel Station indicates a strong northeast flow along the axis of the channel. This and the increase of approximately 65% in flow speed in this region as compared to San Mateo and Ambrosia Lake area strongly suggest the confluence of the drainage from these air sheds. At Flats Station the direction of drainage flow appears to be from north north east indicating the continuation of flow through the channel area. A 24% component at 30° north of east could in part be due to drainage from La Jara Mesa to the east (see Fig. 2).

### 3.2 Vertical Wind Structure During Drainage Flow

A series of measurements of vertical wind structure in the Grants Basin was obtained in the Ambrosia Lake site during the summer and winter experiments in order to investigate the depth of the drainage flow and the atmospheric structure above it. The wind speed and direction at various heights above ground were determined by standard single theodolite tracking of a 30-g pilot balloon (PIBAL). These measurements were conducted at one half to one hour intervals. Each experiment started a few hours after the drainage flow had established, as indicated by the surface instrument, and continued until after the start of temperature rise and surface heating the next morning. The analysis of these measurements (not shown here) indicates that:

1. For most cases, a weak and shallow drainage flow exists even in the presence of strong synoptic winds.

2. The depth of major drainage flow under these conditions is in the order of 50 m.

3. As its development progresses, its effects are seen up to about [illegible] m from the surface.

## 4. Summary and Conclusion

During the short experimental period in the Grants Basin a survey was conducted on the complex meteorology of this area. Emphasis was placed on the nocturnal drainage flow because of the potential hazards to the populated areas of Milan and Grants from the effluents of the uranium mining and milling operation in this area.

This investigation has shown that the nocturnal drainage flow patterns agree with the winds predicted on the basis of the complex terrain of the area. Because of the surface cooling at night (over 25°C during summer and about 20°C during winter) air from elevated surrounding areas flows to the low lying regions consequently setting up a nocturnal drainage flow. This regime exists over 60% of the time during summer months and over [illegible]% of the time during winter months with a depth generally less than 200 m.

In the San Mateo air shed the drainage flow is east northeast, and in the Ambrosia Lake air shed it is from northwest. The confluence of these two air flows contributes mainly to the drainage flow through the channel formed by La Jara Mesa and Mesa Montanosa. The analysis of data collected by the recording Flats Station confirms our prediction that although the area south of the channel region broadens considerably causing a reduction in flow speed, contributions from the southside of La Jara Mesa and Mesa Montanosa (Fig. 2) partly compensate for this reduction. The position of this recording station is 15-20 km from the populated towns of Milan and Grants. A drainage flow speed of approximately 2.2 m $s^{-1}$ and the duration of over 11 hours as recorded by this station indicates that air from the San Mateo and Ambrosia Lake regions may be transported southwards to these population centers during a nocturnal period. In order to test this prediction, a series of multi-atmospheric tracer experiments were conducted in the Grants Basin (Clements, et al. 1980).

## 5. ACKNOWLEDGMENTS


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## 6. REFERENCES


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### TABLE 1 (SUMMER DATA)

COMPARISON OF NOCTURNAL FLOW PROPERTIES FOR GRANTS BASIN

AT THE THREE RECORDING STATIONS

(Mean Values and Ranges)

| Property | San Mateo Station | Ambrosia Lake Station | Channel Station | Units |
|---|---|---|---|---|
| Onset Time | 3.2 ± 1.8, (1 to 8)[a] | 4.9 ± 1.4, (3 to 7) | [illegible] | Hours after the temperature begins to drop in the evening |
| End Time | 0.8 ± 0.7, (-1 to 1) | -1.1 ± 0.34, (-2 to -1) | 0.5 ± 0.58, (-1 to 2) | Hours after the temperature begins to rise in the morning |
| Flow Duration | 8.2 ± 1.8, (4 to 11) | 7.2 ± 1.8, (5 to 11) | 7.4 ± 1.8, (4 to 10) | Hours |
| Flow Speed | 1.8 ± 0.3, (1.2 to 2.5) | 1.8 ± 0.1, (1.3 to 1.7) | 2.5 ± 0.3, (2.1 to 3.4) | m $s^{-1}$ |

[a] Range

### TABLE 2 (WINTER DATA)

COMPARISON OF NOCTURNAL FLOW PROPERTIES FOR GRANTS BASIN AT THE FOUR RECORDING STATIONS

(Mean Values and Ranges)

| Property | San Mateo Station | Ambrosia Lake Station | Channel Station | Flats Station | Units |
|---|---|---|---|---|---|
| Onset Time | 1.8±0.9(0 to 4)[a] | 2.2±0.8(0 to 7) | 0.8±0.15(-1 to 4) | 2.15±0.92(0 to [illegible]) | Hours after the temperature begins to drop in the evening |
| End Time | -0.64±0.11(-0 to 2) | -0.4±0.1(-1,2) | -0.1±0.05(-2,4) | -0.24±0.09(-2 to 2) | Hours after the temperature begins to rise in the morning |
| Flow Duration | 11.1±0.3(7 to 14) | 11.0±0.3(8 to 15) | 11.0±0.3(6 to 15) | 11.1±0.3(8 to 14) | Hours |
| Flow Speed | 1.6±0.08(0.8 to 2.8) | 1.9±0.08(0.8 to 2.6) | 2.42±0.1(1.0 to 3.4) | 2.2±0.1(1.6 to 3.6) | $ms^{-1}$ |

[a] Range

Fig. 1. Contour map of Grants Basin. Elevation contours in feet.

Fig. 2. Locations of weather stations in the Ambrosia Lake and San Mateo area. Elevation contours in feet.

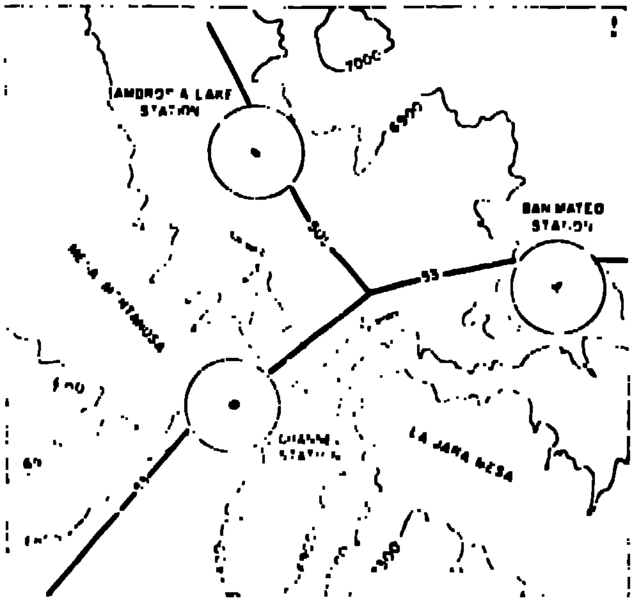


Fig. 3. Summer nocturnal wind roses at three locations in the Ambrosia Lake and San Mateo area.

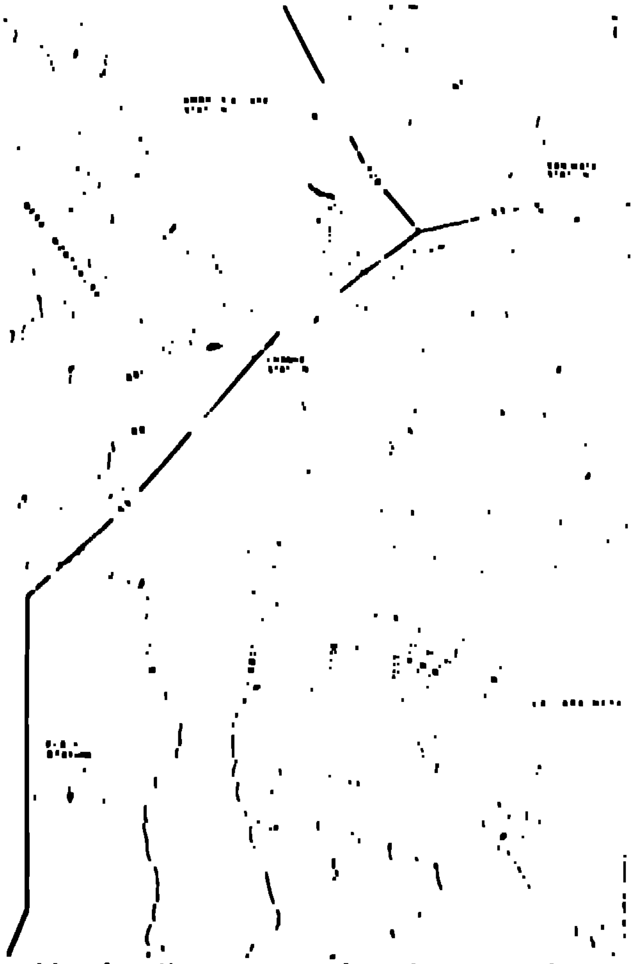

Fig. 4. Winter nocturnal wind roses at four locations in the Ambrosia Lake and San Mateo area.